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The Flow of Water through Sand & Deep Well Strainers

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THE FLOW OF WATER
THROUGH
SAND AND DEEP WELL STRAINERS

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BY

FRANK GORDON HOFFMAN

THESIS

FOR

DEGREE OF BACHELOR OF SCIENCE

IN

CIVIL ENGINEERING

COLLEGE OF ENGINEERING

UNIVERSITY OF ILLINOIS

PRESENTED JUNE, 1907

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C O L L E G E O F E N G I N E E R I N G

May 24, 1907.

This is to certify that the following thesis prepared under the direction of Professor A. N. Talbot, Head of the Department of Municipal and Sanitary Engineering, by

FRANK GORDON HOFFMAN

entitled FLOW OF WATER THROUGH SAND AND DEEP WELL STRAINERS

is accepted by me as fulfilling this part of the requirements for the Degree of Bachelor of Science in Civil Engineering.

Ira O. Baker.

Head of Department of Civil Engineering

247325

The Flow of Water through Sand and Deep Well Strainers.

Aside from a rather unsatisfactory and incomplete discussion in a thesis by N.R. Porterfield there are no published data concerning the capacity of deep well strainers. The peculiar variations in the quantity discharged by strainers with sand, as found by Mr. Porterfield, aroused a desire to determine the reason for such variations, and to establish, if possible, the law governing them. While the data and discussion here presented are claimed to be only a small part of what would be necessary to cover the field as suggested by the title, it is hoped that they may prove of some practical use in the selection of strainers, and above all, serve as a basis for further investigations and experiments until the entire ground has been covered.

For making these experiments no sand from a water-bearing stratum could be secured, so a sand, which by analyses showed itself not very unlike the Eureka, Del., well sands, was selected. The results of the mechanical analysis of this sand are shown on Plate I. Page 11.

From this is seen that the sand is fairly coarse-fine gravel in fact - with but a small percentage of clay and finely divided material. It is quite uniform, having a uniformity co-efficient of 2.67 and 38 per cent of voids, from which one would expect a proportionate heigh rate of discharge

The strainers tested were three Cook strainers, #'s 6, 10, and 20; two Johnson, #'s 10 and 20; two Henion and Hubbel, #'s 10 and 20; and one American Well Works strainer. A third Johnson #30 strainer was broken while attempting to force it into the sand after the Cook #10 had been removed. The Cook and the American Well Works strainers were the same as tested by Mr. Porterfield. The strainers are shown and described in detail on Plates II to V. Pages 12 to 15.

The tank, designed and built for these tests, and the arrangement of the apparatus is shown on Plate VI. Page 16. The cover was raised by means of a turn-buckle fastened to an improvised dolly which ran on a 4" x 4" timber supported on the lower flanges of the floor-beams above. By this means the cover was moved from above the tank.

Owing to the long time variations shown by Mr. Porterfield's curves it was thought advisable

to put in some kind of automatic head regulator, so that tests might be run continuously under uniform heads for long periods. A regulator tank supplied by a 1-inch entrance pipe and 1½-inch exit was first swung from a pulley and connected to the entrance pipe B and to the main standpipe in such a way that by the insertion of additional lengths of pipes the heads on the strainer could be varied 10 ft. 20 ft. and 27 ft. But it was found that, with the coarse and uniform sand permitting such a high discharge, the 1½-inch exit pipe was not large enough to furnish even the quantity of water required by the Cook #20 under a 10 ft. head. The regulator tank was then removed and automatic regulation of the head was secured by the overflows as indicated in the drawing. By adjusting the throttling valve (B, Plate VI) at the entrance to the 3-inch standpipe until a small stream of water issued from the lowest open overflow, the head on the strainer was kept fairly constant during any reasonable variation of head in the 4-ft. standpipe.

The overflows were arranged to give 10 ft. 20 ft. and 28½ ft. 8 in. heads on the exit of the strainer pipe "J", but owing to losses in the entrance

pipe and at "F" these heads were never attained inside the tank. The heads as recorded are those shown by the gage reading from gage pipe # 4 when this pipe was pulled outside the sand, minus 3 ft. for difference of level between the gage and "J". (For the arrangement of the gage pipes see the drawing, Plate VI.) The heads for any one overflow varied with the different strainers because of the higher entrance losses with increased discharge. Owing to the whirling of the water at "B" considerable air was entrapped at "C" when this overflow was open, and it was found necessary to keep the air-cock "K" partly open to allow the escape of this air after it had been carried into the tank.

The sand was put in and compacted by pressing it down with the foot. When compacted this way no appreciable settling or raising of the sand was observed. It was piled up well above the top of the strainer, nearly to the top of the flange elbow. To replace a strainer with one of larger diameter it was necessary to take out the sand. A strainer of a diameter the same as the one removed could be inserted without removing much of the sand.

The rate of flow was determined by weighing the discharge during a given time. The weight of

water was taken at 8⅓ pounds per gallon. Gage readings 1, 2, 3, & 4 and the rate of discharge were taken at frequent intervals, 5 to 7 times per hour. The amount and variation of discharge with time for the several strainers is shown on Plates VII to XIV, Pages 17 to 24. Plate XV. Page 25, shows the capacities for the various strainers for different heads outside the sand, and Plate XVI P.26, shows the same for the heads next to the strainer as shown by gage # 1. Plates XVII and XVIII, Pages 27 and 28, show the losses of head for the various tests with the proportionate velocities at the points at which the gage readings were taken.

The data will be studied under three heads:

I. The Relation of Discharge to Time.

II. The Relation of Discharge to Head.

III. The Flow through the Sand.

I. The Relation of Discharge to Time: This relation is shown by the first set of curves, Plates VII to XIV Pages 17 to 24. A study of these curves enables one to draw the following conclusions:

(a) There is usually a variation in discharge at the beginning of the test.

(b) The discharge after an hour or so becomes

Constant and continues so.

It appears that the variation in discharge at the beginning of a test may be either an increase or a decrease: When the conditions are such, that with a continuation of the test, the sand settles more, the flow may be expected to decrease; and, when at the beginning of the test, the sand is more closely packed than the conditions call for, the water will loosen it and the flow increases. Plates XII and XIV, Pages 22 and 24, show the most marked ~~low~~ discharges at the start. A study of the gage readings, shown on the same plates, shows that the low discharge at the start was accompanied by a high loss of head between gages #4 and #1. As this loss decreased, the discharge increased;- A decrease of the loss of course meant an increase of head on the strainer, gage #1 readings, and it was this increase of head which caused the increase in the discharge. Where the discharge decreases the difference of losses is less marked. Plate XIII, Page 18, shows examples of this. The variations of discharge here however are much smaller than those cited above. Here the loss of head increased but slightly with the decrease of discharge. These instances all point to the same thing, namely, that the cause for the vari-

ation of the discharge lies in the sand itself and not in the relation of the sand to the strainer. When once the head on the strainer became constant the discharge was constant.

II. The Relation of Discharge to Head: This relation is shown by Plates XV and XVI, Pages 25 and 26. Both the head outside the sand and the head inside the sand are plotted. The general character of the two sets of curves is the same, but it is noticeable that the plot with the head inside the sand gives the more nearly uniform results. This is most marked with the curves for the Cook # 20 strainer.

From comparisons between the curves and plotted parabolas we conclude: The discharge of strainers with sand varies with some power of the head, which is greater than one-half but less than unity. The curves on Plate XV for the strainers Cook #'s 10 and 20 throw some doubt as to the correctness of this conclusion: They become much flatter than the others, and the Cook # 10 curve even passes through a point of inflection and becomes convex toward the "head" axis. (This by a third point which in plotting falls off the plate.)

It is of interest to note also, that on the two plates

The curves for the two Henion and Hubbel strainers inter-change positions. This is true of several strainers but it is of special interest for these two because they are so nearly alike. That the #10 strainer gives as great a discharge, and even greater, than the #20 is also of interest. Perhaps the sand grains wedge themselves into the larger meshes of the #20 more than into those of the #10.

III. The Flow through the Sand: Plates XVII and XVIII attempt to show some relation between the head lost and velocity in the flow of water through sand. The loss of head plotted is always the total loss from a point outside the sand to the point considered, as shown by the difference of pressure at those points. It was assumed that the velocity varied directly with the discharge and inversely with the distance from the center of the strainer. This last is strictly true only when the water approaches the strainer in a line perpendicular to the strainer's axis. This condition is not exactly met, but it is thought that the error thus introduced will not be large enough, to alter materially the general form of the curves. There appears to be a great variation in the head lost for equal velocities due to the various heads,

but the element of distance which the water has flowed through the sand (which has not been duly provided for in these curves) enters into the problem in so complicated a manner that it might, when eliminated, cancel this apparent variation. all curves however point to the same thing in one respect — the head lost varies with some power of the velocity which is less than unity, and in some of the curves appears to be even less than one half. The head lost seems also to depend upon some strainer factor. This inter-dependence is hard to understand, and certainly calls for further investigations and experiments before even a guess as to its reason may be hazarded.

The conclusions drawn as a result of these tests and investigations may be summarized as follows:

1. Under a constant head and unvarying conditions in the sand, the discharge of strainers with sand is constant.

2. Changing conditions within the sand produce varying losses of head in the flow of water through it.

3. The arrangement of the particles of sand is fixed by the water flowing through it; and such arrangement, when once established, is not likely to be altered.

4. Within limits the head lost in water flowing through sand varies with some power of the velocity less than unity.

5. The discharge of a strainer varies approximately with the square root of the head.

6. Strainers differ widely in their relative capacities.

PLATE I

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MECHANICAL ANALYSIS OF SAND

Test No. ____

Sample from Kentucky

Analyzed by F.G. Hoffman

Date of collection April 17. 1907

Date of analysis May 22. 1907

Remarks Pit sand - Purchased from Sheldon Brick Co.

Amount Analyzed = 500 grams

Sieve No.	Separation Size mm.	Amount Passing Grams	Amount Passing Per cent
5	4.417	494.2	97.8
10	2.320	427.7	85.5
12	1.699	392.5	78.5
18	1.080	272.3	54.5
30	0.684	145.1	29.0
40	0.490	60.5	12.1
50	0.320	15.1	3.0
74	0.225	6.8	1.4
130		4.1	0.8
200		3.7	0.7

Spec. Grav. = 2.68 Voids = 38 o/o Effective Size = .45 mm. Uniformity Coeff = 2.67

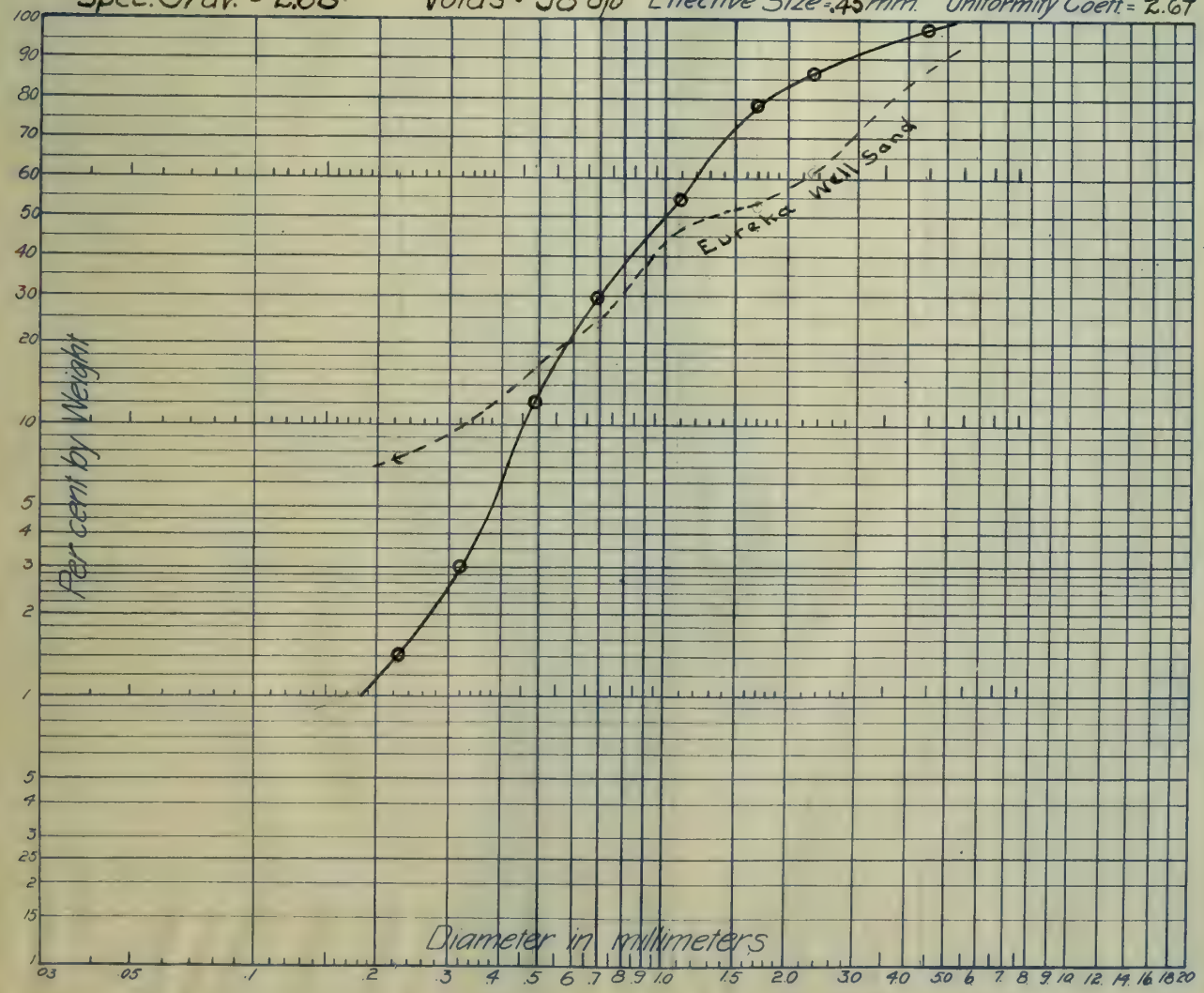
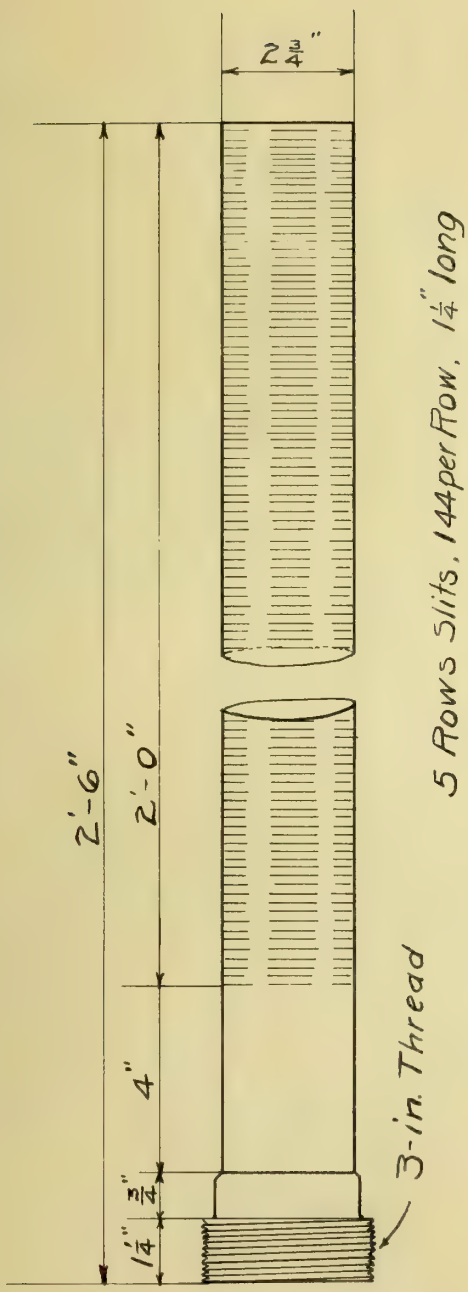
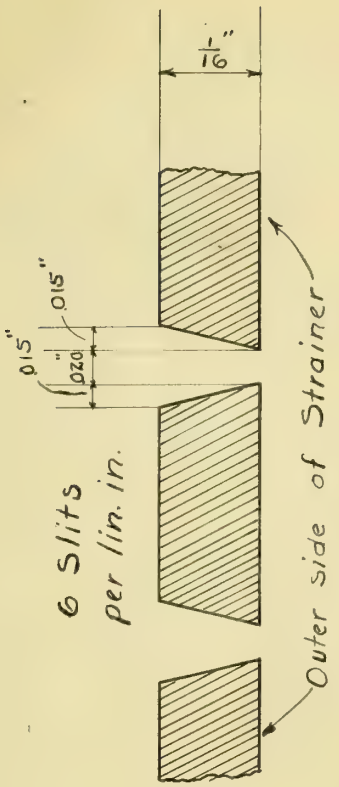


PLATE II



Cook Strainer



Section of Side of Strainer Showing Details of Slit. Dimensions of Slit are for Cook #20 - Widths are proportional to given Nos.

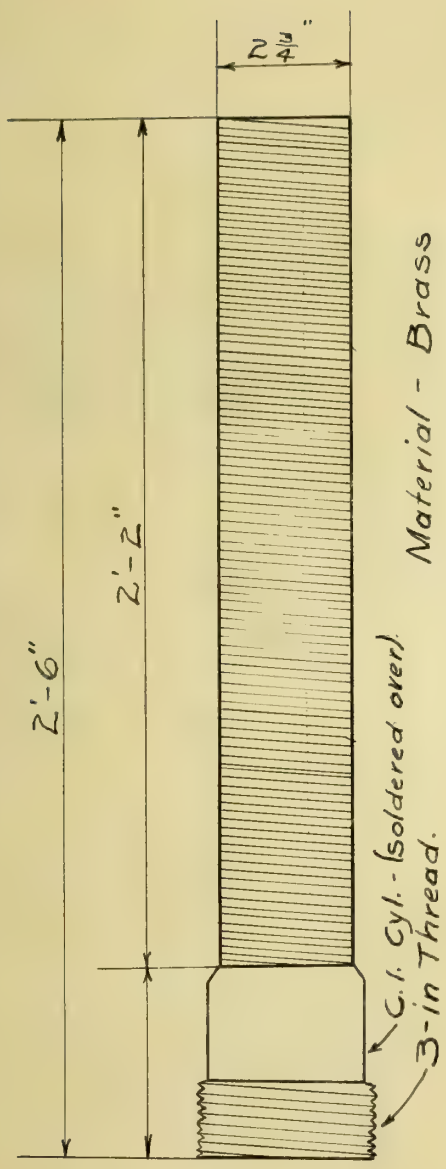
Details of Cook Strainers Nos. 6, 10, and 20

Strainer Area = 1.44 sq. ft.

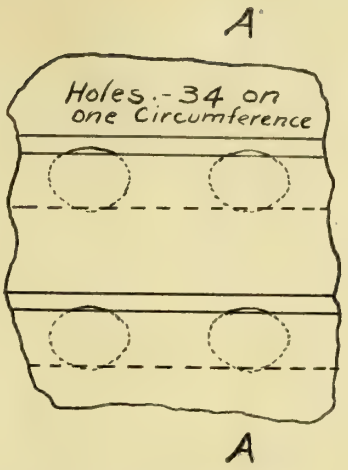
Widths of Slits: - ins.

Cook # 6	0.006
Cook # 10	0.010
Cook # 20	0.020

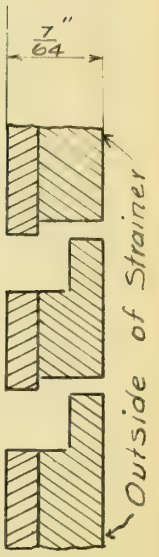
PLATE III



Johnson Strainer



Surface View



Section AA
Side of Strainer

This Strainer consists of a center brass shell containing many holes, wrapped spirally with a brass strip, leaving a continuous spiral slit the full length of the strainer.

Details of Johnson Strainers Nos 10, 20 and 30

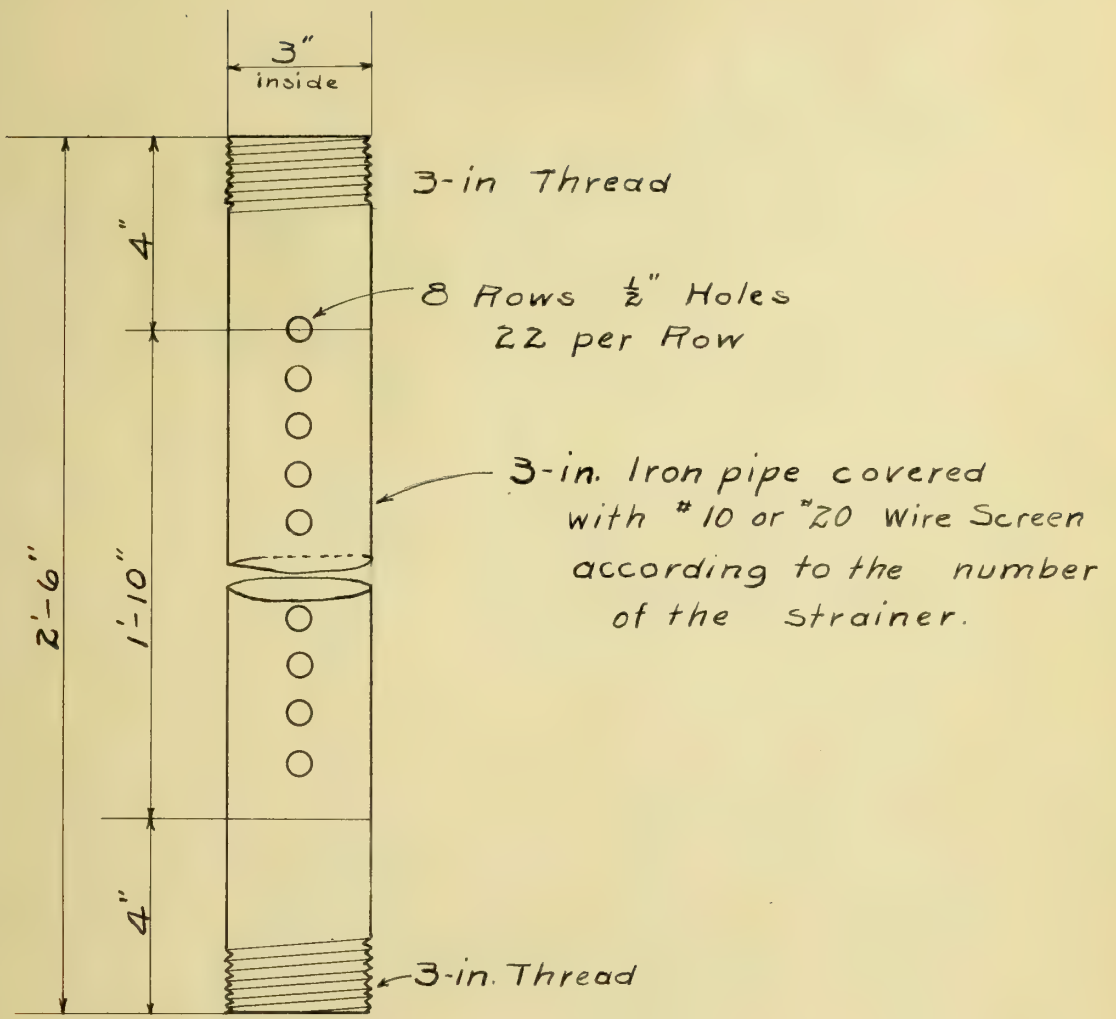
Strainer Area = 1.56 sq.ft.

48 lin. ft. of Slits per lin. ft. of Strainer

Widths of Slits:

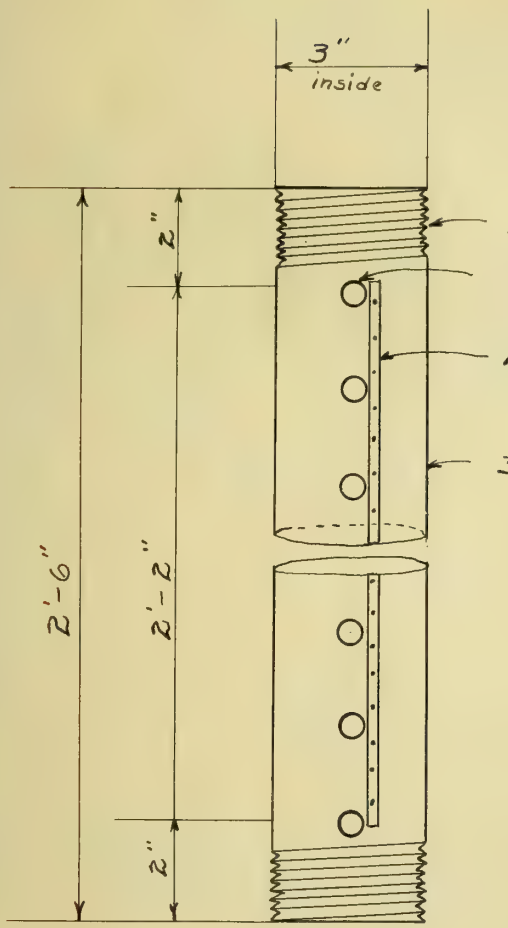
No. 10 - 0.010 in
No. 20 - 0.020 in
No. 30 - 0.030 in

PLATE IV



Details of
Henion & Hubbel Strainers
Nos 10 and 20
Strainer Area = 1.70 sq.ft.

PLATE V



3"in. Thread

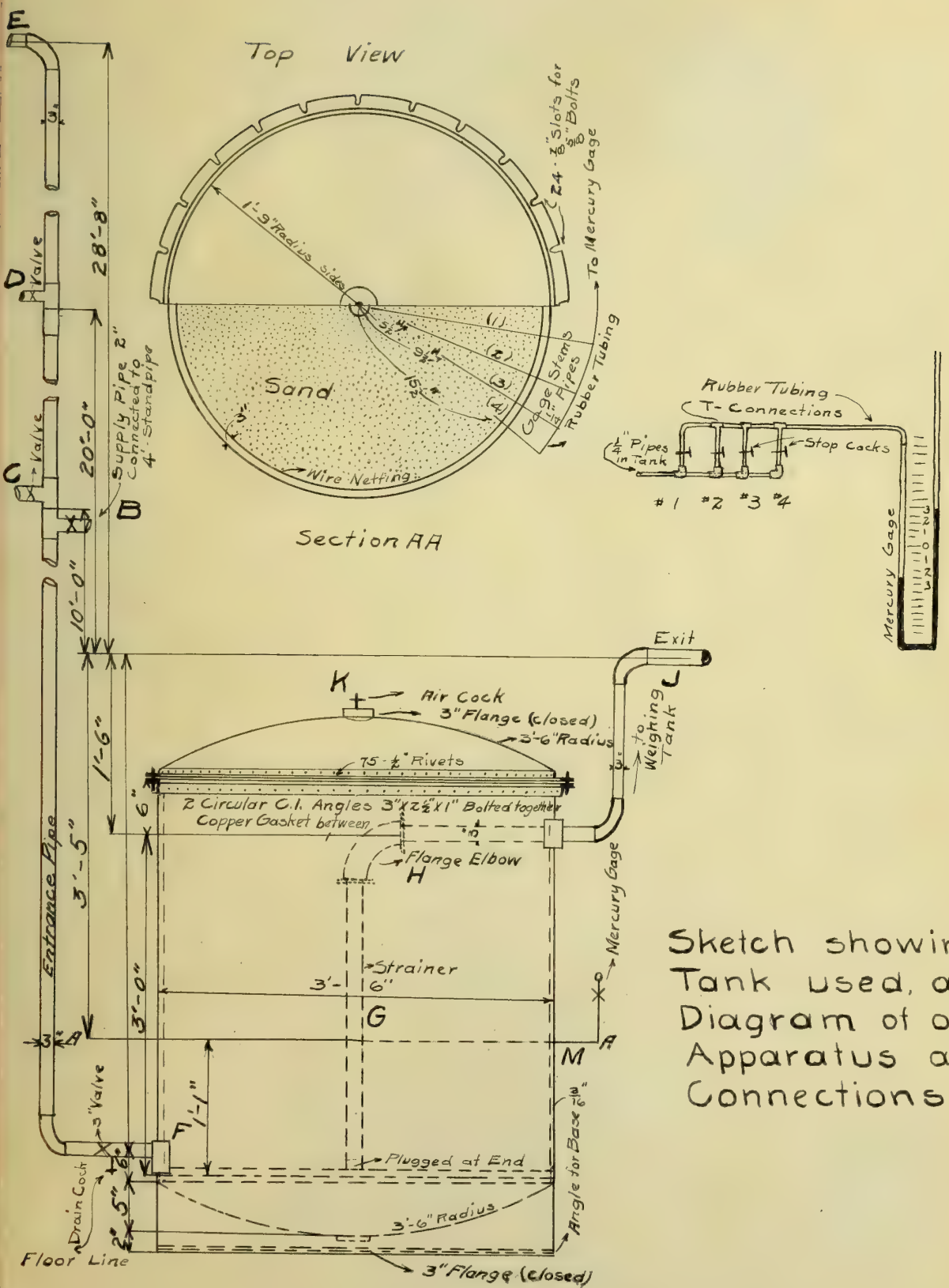
6 Rows ½" Holes - 12 per Row

Iron Strap - 3 in no.

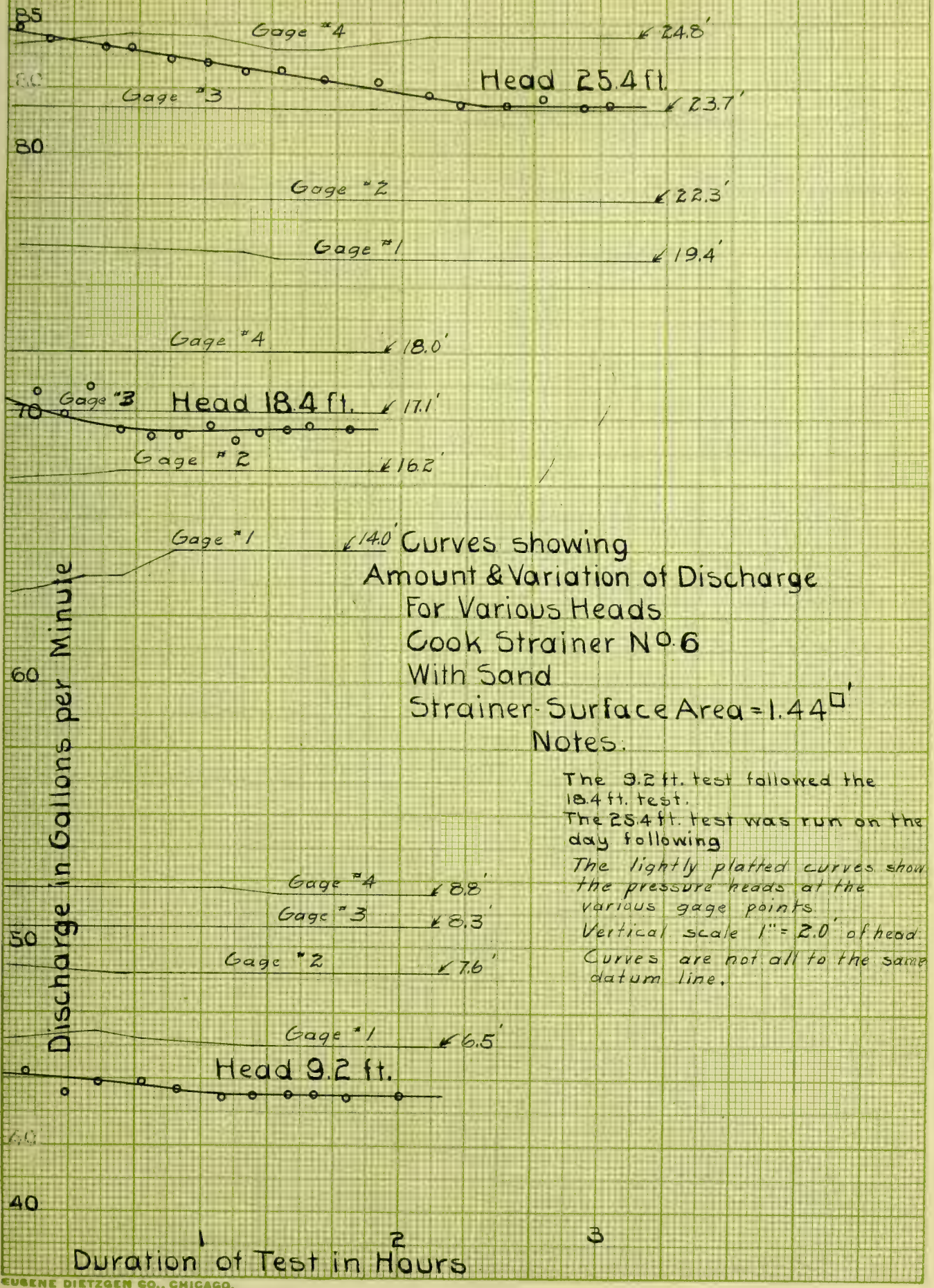
3-in. Iron pipe covered with coarse Wire Netting and over this Copper Gauze, held by Iron Strap shown.

Details of
American Well Works
Strainer
Strainer Area = 1.96 sq.ft.

PLATE VI

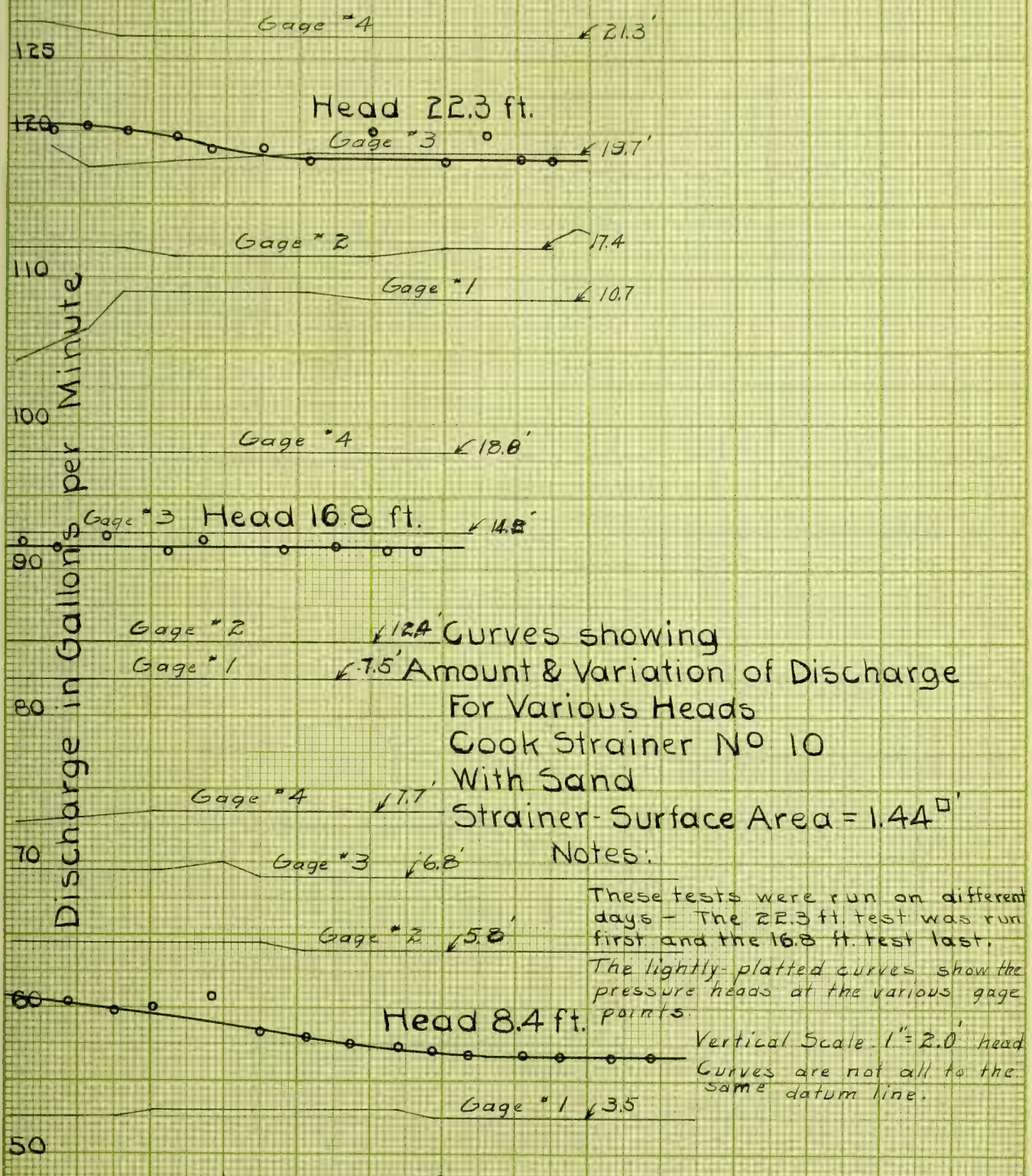


Sketch showing Tank used, and Diagram of other Apparatus and Connections



EUGENE DIETZGEN CO., CHICAGO.

PLATE VIII



Curves showing Amount & Variation of Discharge For Various Heads Cook Strainer No 10 With Sand Strainer - Surface Area = 1.44 □'

Notes:

These tests were run on different days - The 22.3 ft. test was run first and the 16.8 ft. test last.

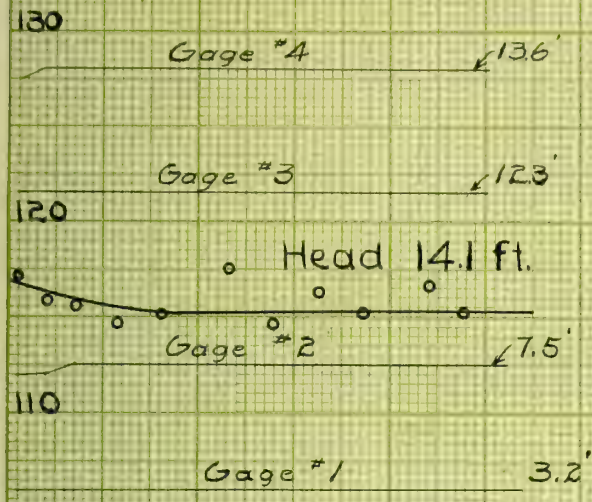
The lightly-platted curves show the pressure heads at the various gage points.

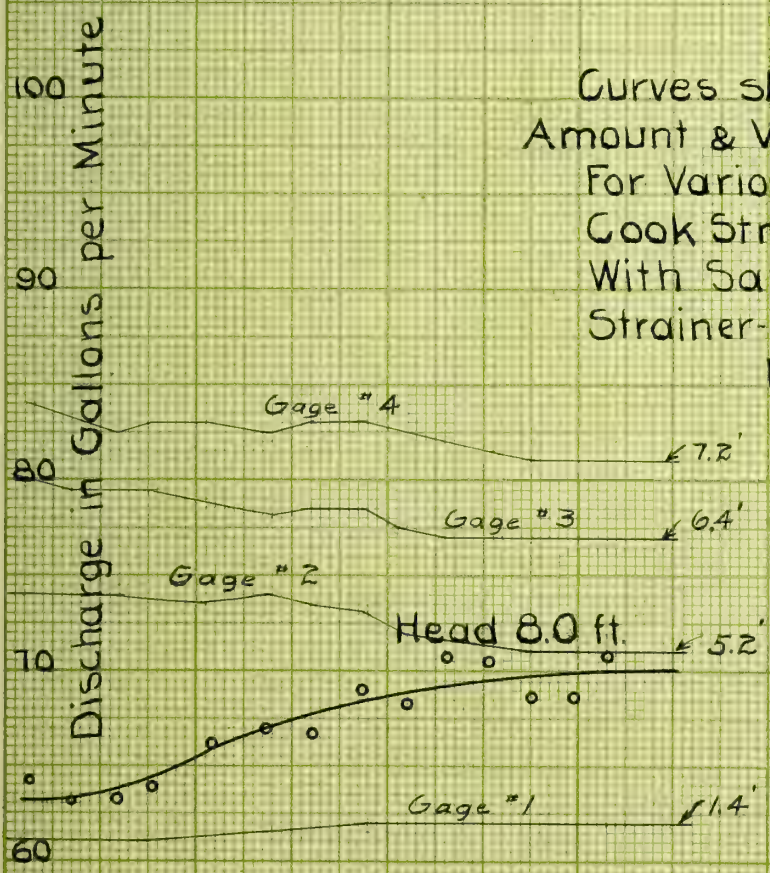
Vertical Scale 1" = 2.0' head

Curves are not all to the same datum line.

EUGENE DIETZGEN CO., CHICAGO.

PLATE IX





Curves showing Amount & Variation of Discharge For Various Heads Cook Strainer No. 20 With Sand.

Strainer-Surface Area = 1.44 □'

Notes:

The 14.1 ft. head was run on the day following the 8.0 ft. head. The water was shut off in the meantime.

The lightly platted curves show the pressure heads at the various gage points

Vertical Scale 1" = 2'.0 of head.

Curves are not all to the same datum line.

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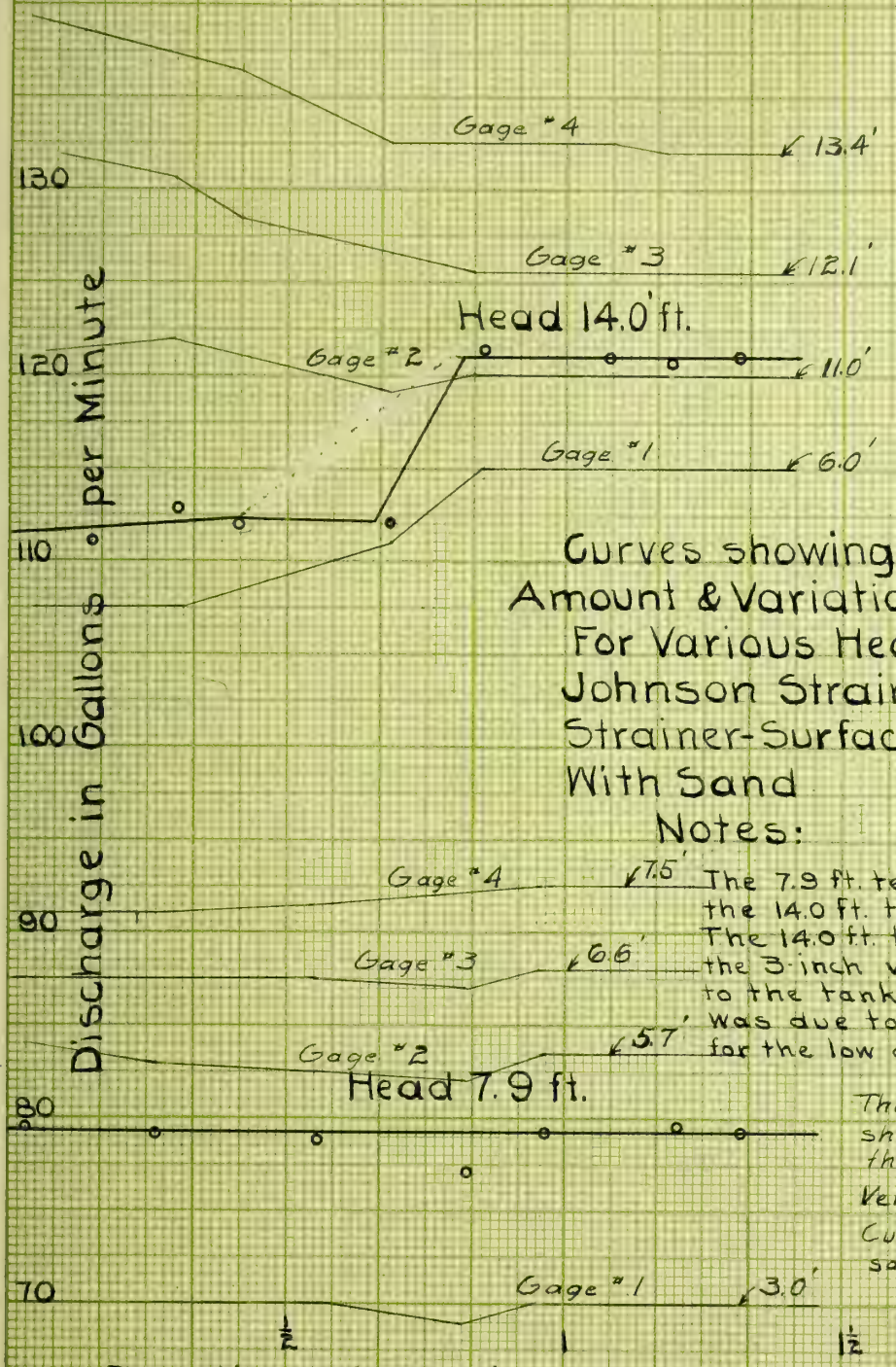
PLATE X



Curves showing Amount & Variation of Discharge For Various Heads Johnson Strainer No. 10, Strainer-Surface Area = 1.56 □', With Sand

Notes:

The 7.9 ft. test immediately followed the 14.0 ft. test. The 14.0 ft. test was started with the 3-inch valve at the entrance to the tank partly closed. This was due to accident and accounts for the low discharge at the start

The lightly platted curves show the pressure heads at the various gage points.

Vertical Scale: 1" = 2.0' head

Curves are not all to the same datum line

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PLATE XI

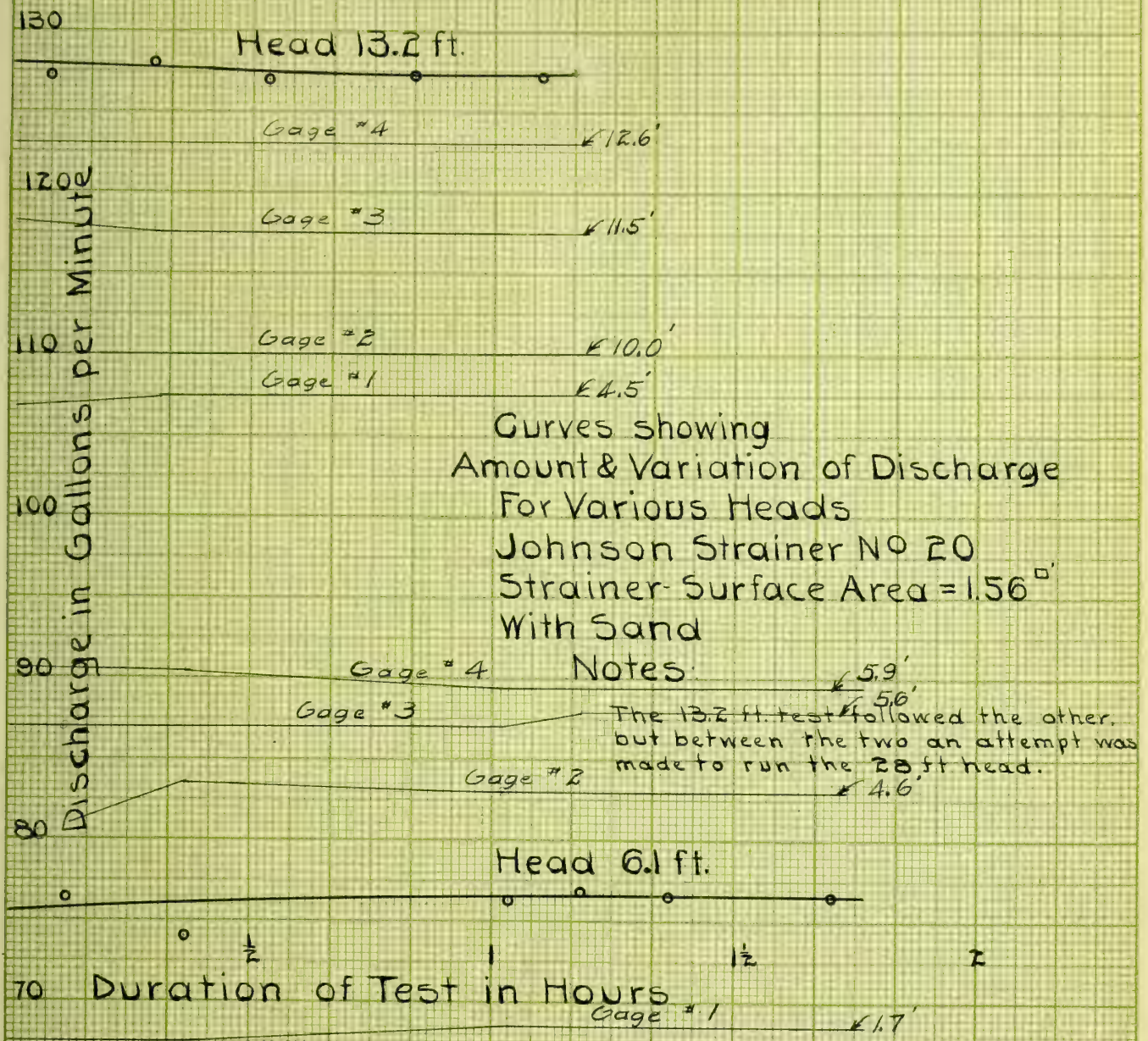

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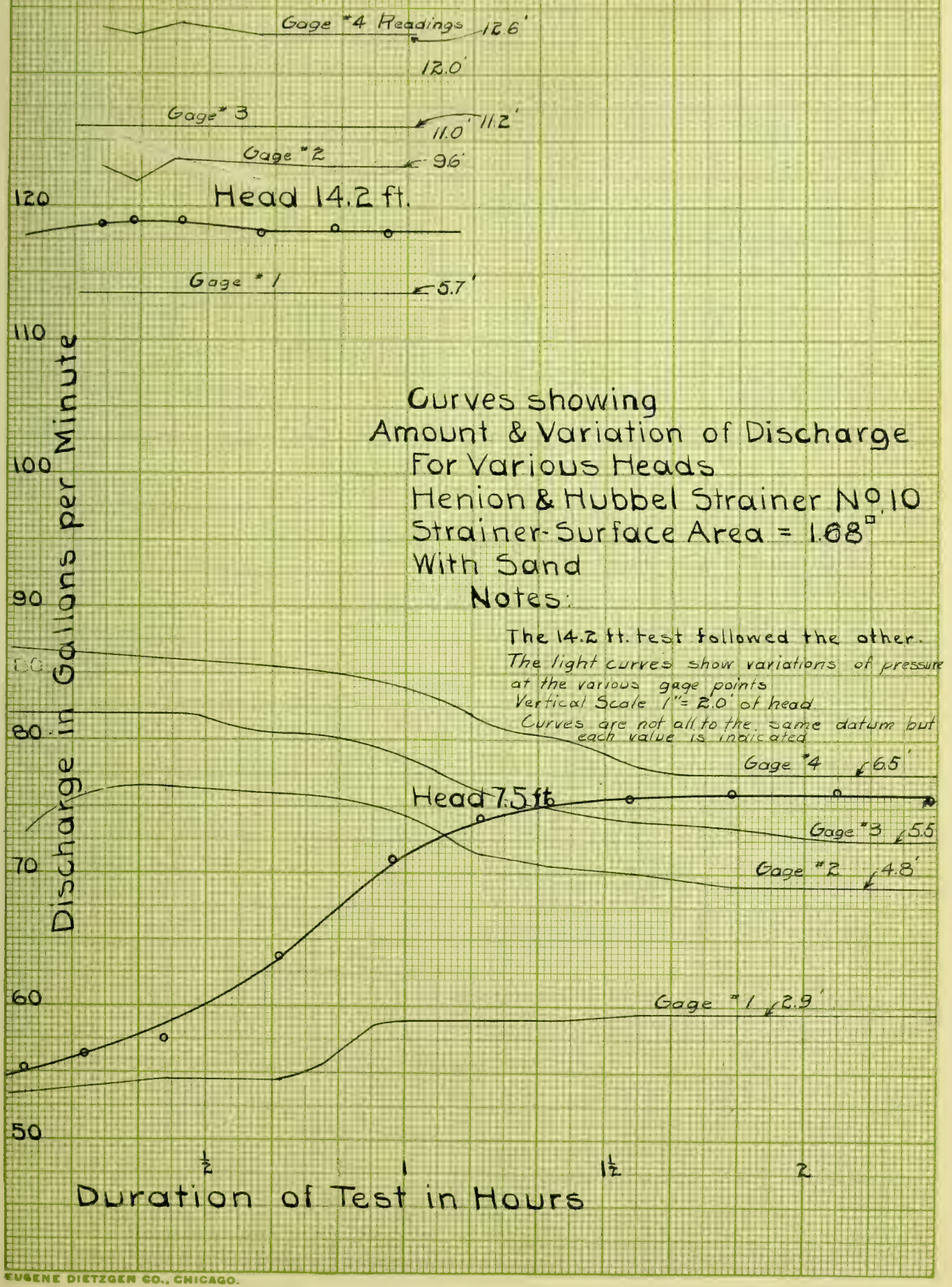
PLATE XII



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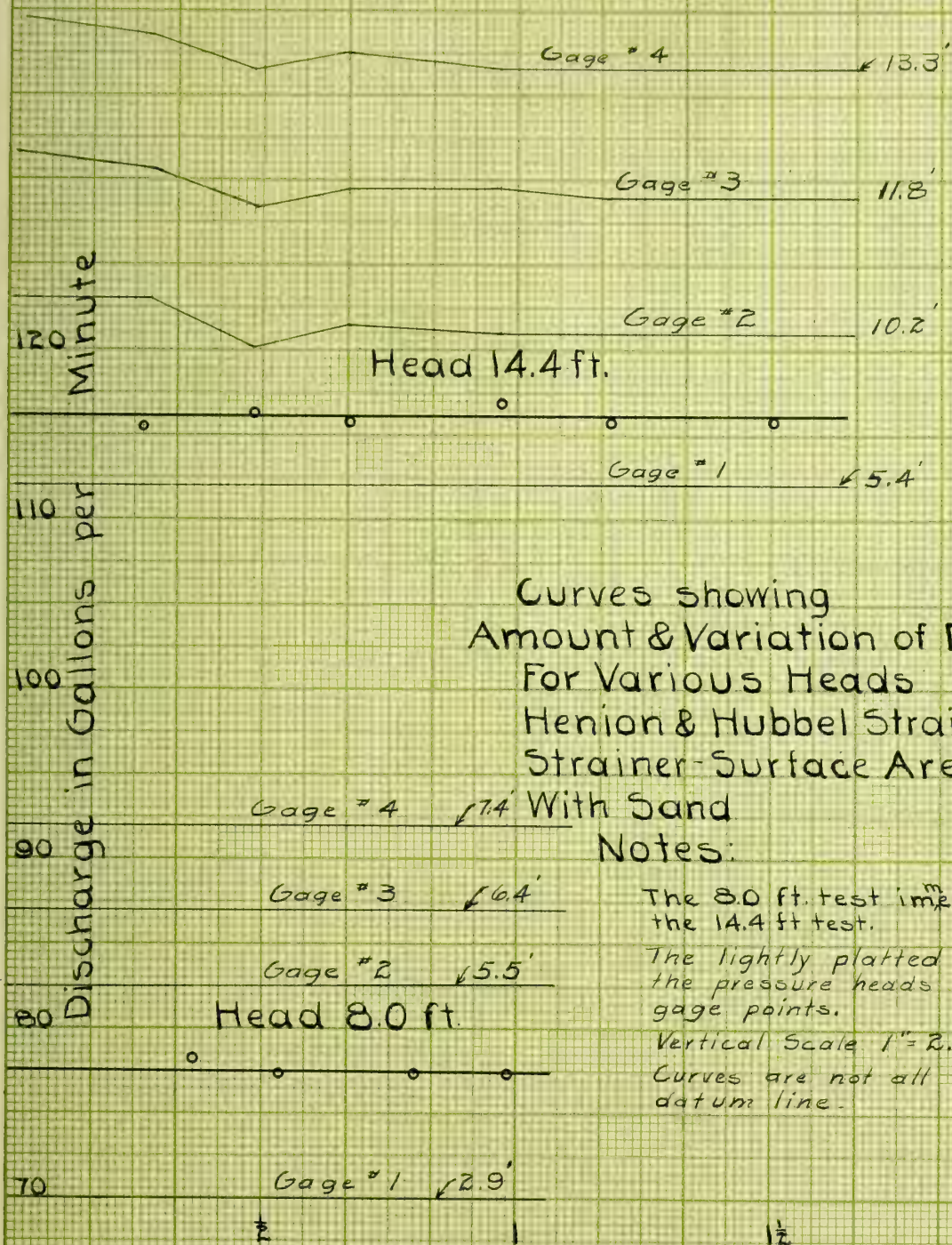


Curves showing Amount & Variation of Discharge For Various Heads Henion & Hubbel Strainer No 20 Strainer-Surface Area = 1.68 □' With Sand

Notes:

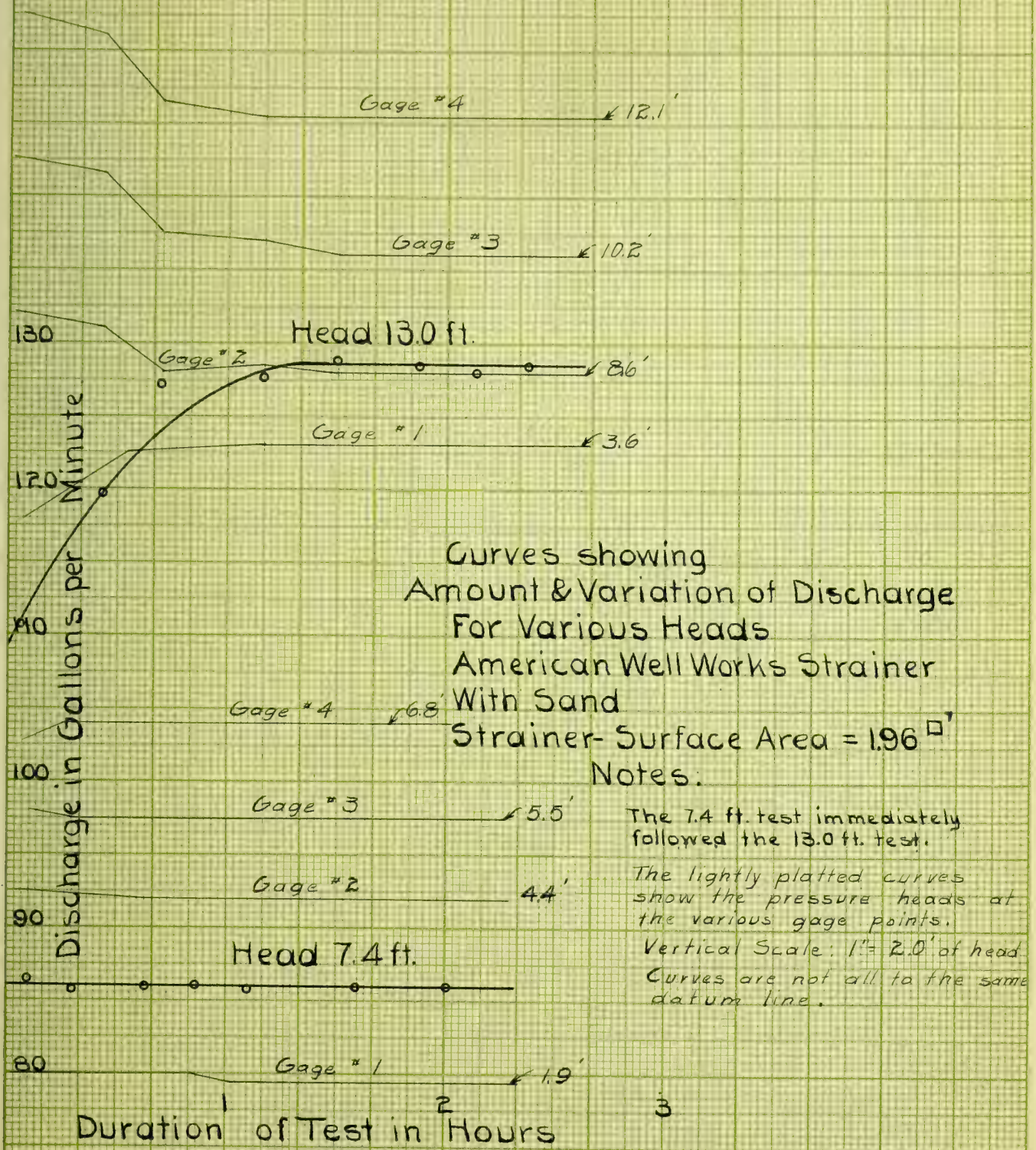
The 8.0 ft. test immediately followed the 14.4 ft test.

The lightly platted curves show the pressure heads at the various gage points.

Vertical Scale 1" = 2.0' of head.

Curves are not all to the same datum line.

EUGENE DIETZGEN CO., CHICAGO.



Curves showing Amount & Variation of Discharge For Various Heads American Well Works Strainer With Sand Strainer- Surface Area = 1.96 □'

Notes.

The 7.4 ft. test immediately followed the 13.0 ft. test.

The lightly platted curves show the pressure heads at the various gage points.

Vertical Scale: 1" = 2.0' of head.

Curves are not all to the same datum line.

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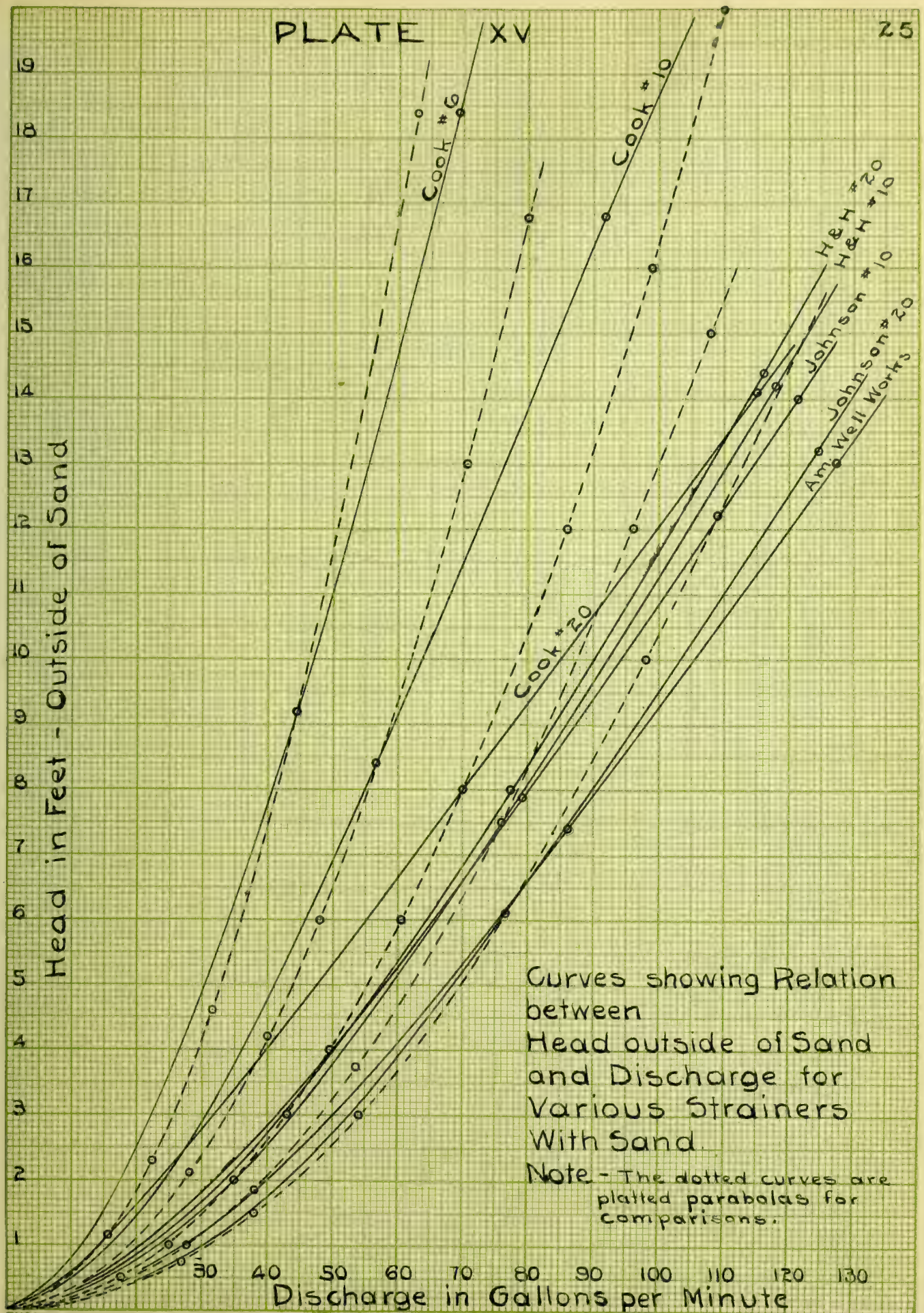
PLATE XV

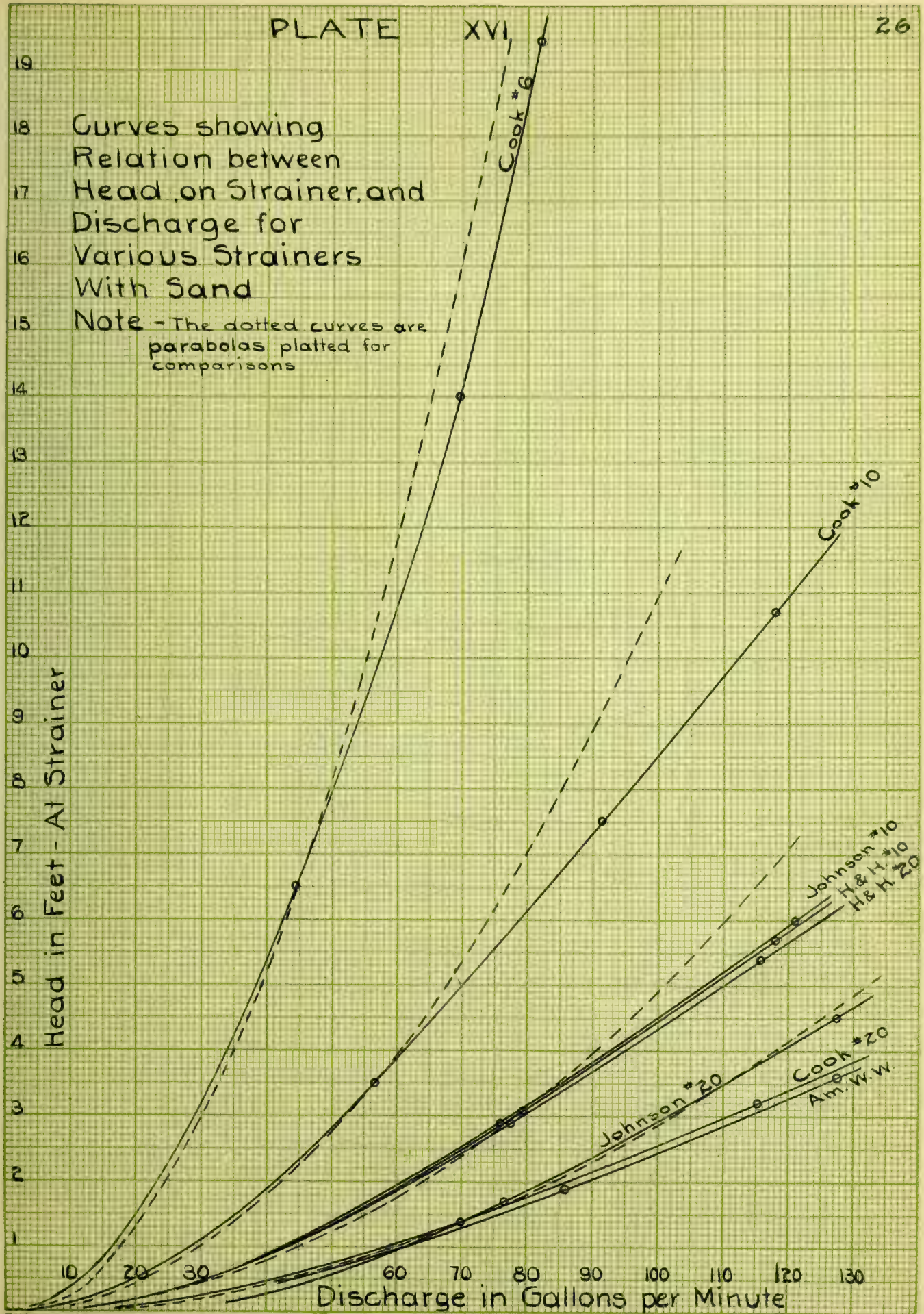

Head in Feet - Outside of Sand
Discharge in Gallons per Minute
Cook #6
Cook #10
Cook #20
H&H #20
H&H #10
Johnson #10
Johnson #20
Am. Well Works
Curves showing Relation between Head outside of Sand and Discharge for Various Strainers With Sand.
Note - The dotted curves are plotted parabolas for comparisons.

EUGENE DIETZGEN CO., CHICAGO.

PLATE XVI

Curves showing Relation between Head on Strainer and Discharge for Various Strainers With Sand

Note - The dotted curves are parabolas platted for comparisons



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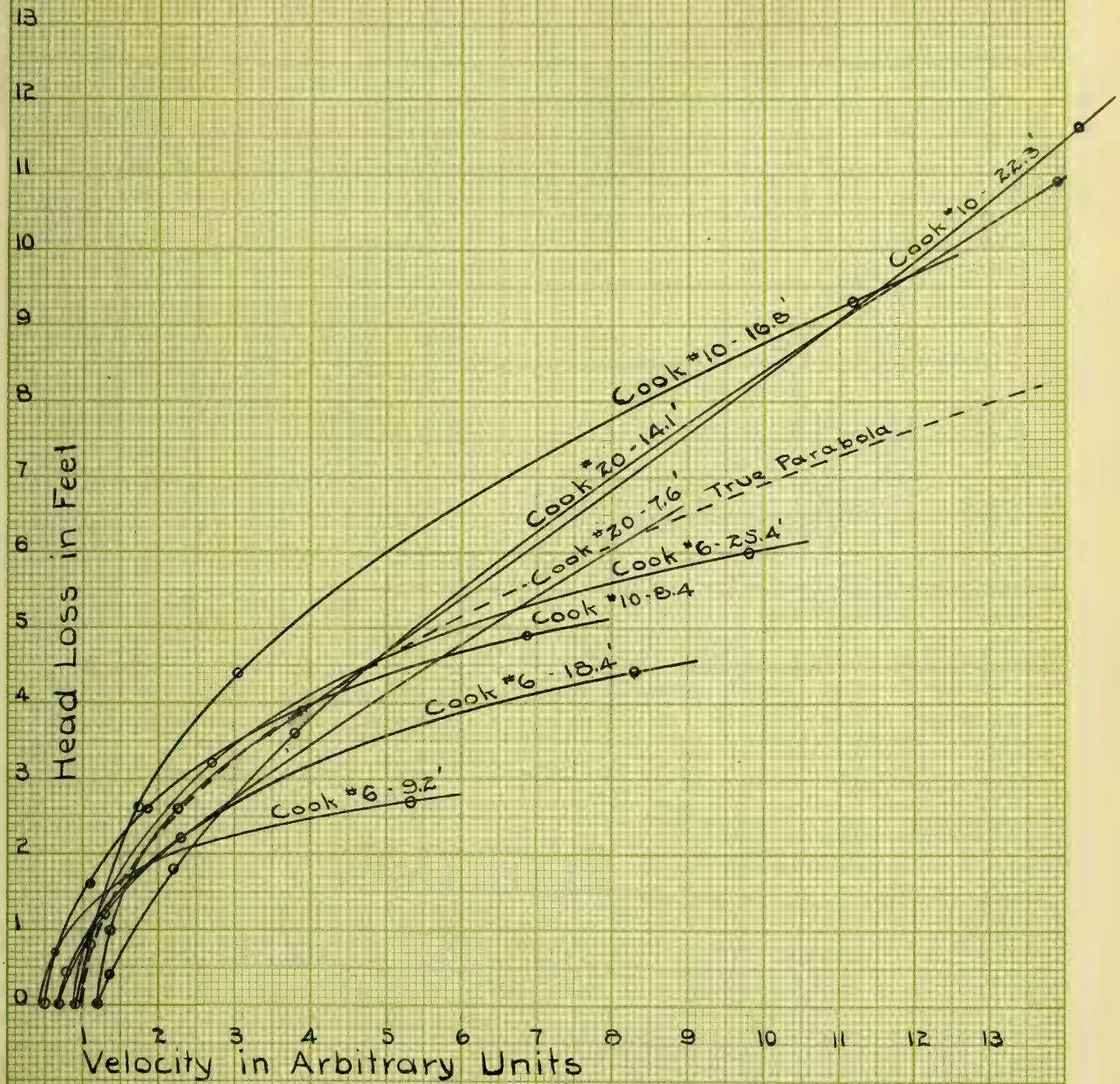

Curves showing Relation between Head Loss and Velocity through Sand for Various Cook Strainers and Various Heads

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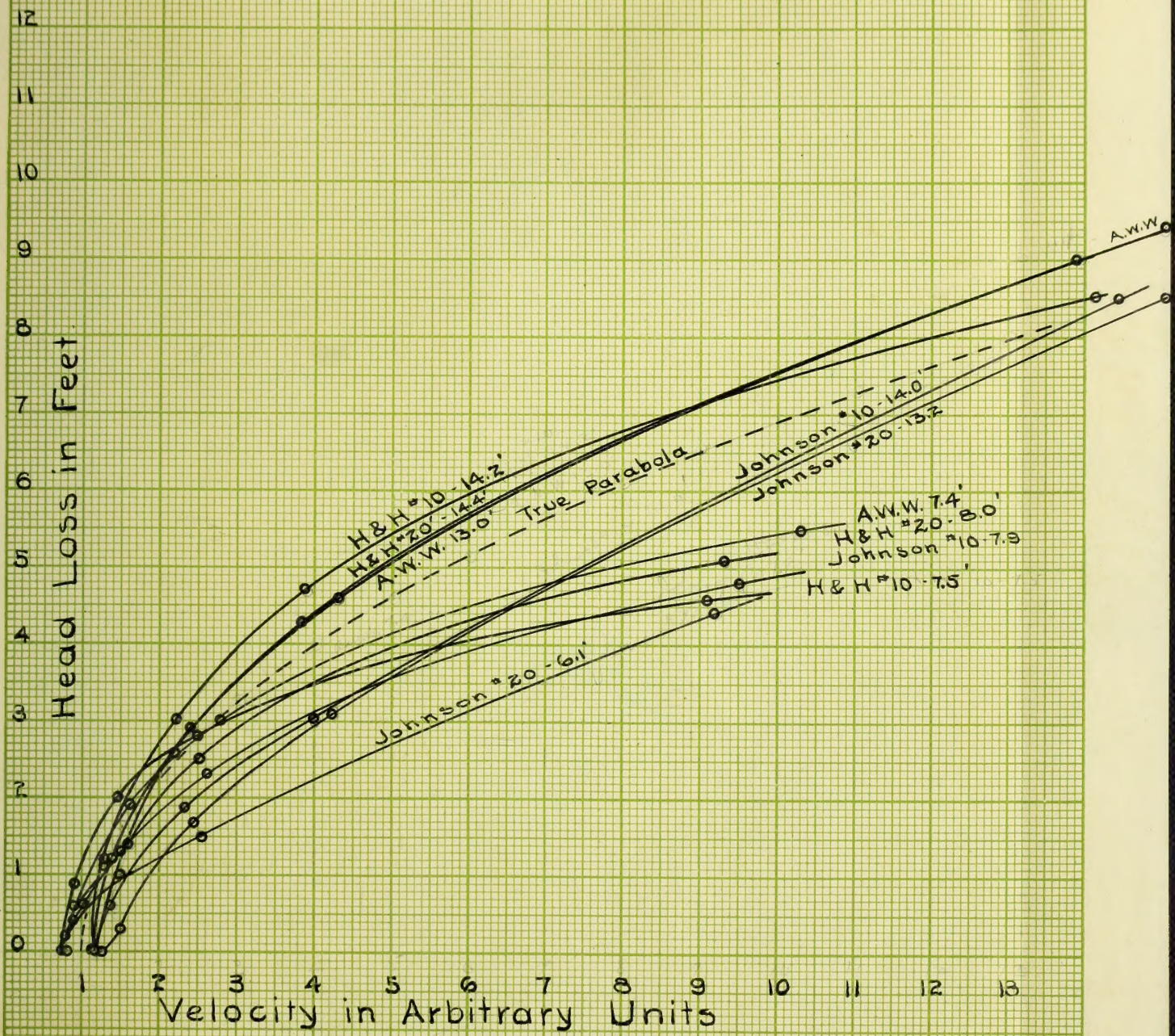

Curves showing Relation between Head Loss and Velocity through Sand for Various Strainers and Various Heads

EUGENE DIETZGEN CO., CHICAGO.